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Study on the fuzzy analytic hierarchy integrated evaluation method of Eco-Industrial Parks

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Abstract

With an escalating conflict between economic growth and environment, eco-industrial parks' evaluation gradually becomes a hot topic in the academic field. On the basis of previous research, this article built up the evaluation index system of the Eco-Industrial Parks, Then evaluated the project by using the fuzzy analytic hierarchy integrated evaluation method.

Keywords: Eco-Industrial Parks; evaluation index system; analytic hierarchy; fuzzy theory

1. The present research situation of our eco-industrial parks' assessment

With the eco-industrial parks' construction and development, the evaluation method has become a hot topic in academia, and many experts at home and abroad have developed generous study in this area. The present research has focused two aspects, That is building evaluation index system and selecting evaluation method.

1.1 The evaluation index system

On this field, the more representative research would be introduced. Jiongliang Yuan [1] decomposed the evaluation index to four indexes: economy, ecological surroundings, ecological network and management index. Haifeng Huang[2] built the system from four aspects, that is economy, environment, management and ecology, then selected 18 second-class indexes. Qiang Li[3] advanced four first-class

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indexes, sustainable development, economical index, management index and ecological environment index, then decomposed 9 second-class indexes. Qi Qiao[4] provided four first-class indexes, economical development, material reduction and recycling, pollution control and the parks' management, then decomposed 21 second-class indexes. Chenkao Zhang[5] took the goal of the eco-industrial parks' Sustainable development ability decompose 10 norm layers, such as the ecological networks' stability, the environment quality, the economical performance, etc. then provided 36 related indexes as index layer.

However, the present existing research could not reflect the eco-industrial parks' running law and development situation, and the index system was very complicated. According to statistics, there were 440 related indexes. Now we have not the evaluation index system which was known publicly, simple and easy. So it is necessary to design a index system which could evaluate accurately the parks' development situation, it can provide decision endorsement to the parks' next development.

1.2 The evaluation methods

(1) Fuzzy math evaluation methods

Yanhong Hao[6] evaluated the thermal power plant eco-industrial parks like this. She determined the index weight by using AHP, and established the fuzzy comprehensive evaluation model, then quantified the constraints to take mathematical solution. It was considered that overcame the present research' shortage, that is based on qualitative description and the comprehensive evaluation has not been carried out.

(2) The gray theory analysis method

There was different level index for the evaluation objects. So the whitening matrix and the whitening function of decision gray type could be constructed respectively, then we can discharge order by calculating all levels' gray statistical decision matrix and comprehensive weight. Haifeng Huang [2] analyzed and evaluated the eco-industrial parks by using the gray clustering method, Chenkao Zhang constructed the eco-industrial parks' model based on the gray theory, and then conducted the case study.

(3) The AHP method

By using AHP, Chengkao Zhang [5] constructed the comprehensive evaluation model, proposed respectively the treatment way of qualitative and quantitative indicators, and then evaluated the Cheng-Du high-tech zone. Yanli Wang constructed the eco-industrial parks' flexible model by using AHP, too.

(4) The distance function model

By using the revised distance function model, Xiaomei Sun etc. [7] calculated the integrated distance value of the indexes' status points to the target points. According to the AHP combining the expert scoring method, the weight could be determined. And referencing the related standards by the state, the industry standards and the parks' development plan, the target points could be calculated. Then the status level could be judged according to the integrated distance value. The conclusion could distinguish the parks' existing advantages and problems intuitively and scientifically.

From the above analysis, the multi-index evaluation method has taken the mainstream among the eco-industrial parks' evaluation method. As the parks' input-output activities are a very complex system project, it has numerous uncertainty and ambiguity. Using the multi-level fuzzy comprehensive evaluation method can solve this problem better.

2. Constructing the eco-industrial parks' evaluation index system

According to the eco-industrial parks' features and the principles of scientific, objective, practical and operability, the index system which can meet the need of the eco-industrial parks evaluation has been refined and constructed, seeing table 1.

3. Constructing the multi-level fuzzy comprehensive evaluation mathematical model

3.1 Constructing the comprehensive evaluation hierarchical structure model

Constructing the comprehensive evaluation hierarchical structure model, Seeing table 1.

Table 1. the eco-industrial parks' evaluation index system

The target layer O	The effect layer A	The element layer B	The index layer C
The eco-industrial parks' evaluation	Economic index A_1	Industry scale and anagement B_1	Industrial assets C_1
			Growth rate of industrial added value C_2
			Growth rate of taxes income C_3
		Industry quality B_2	The proportion of high-tech output value in gross industrial output value C4
			The proportion of leading industry output in the parks' gross value C_5
	Social index A_2	Employment B_3	Solving employment labor C_6
			Labor security C_7
		Technology innovation B_4	The proportion of technological personnel C_8
			Conversion rate of technological achievements C_9
			Contribution rate of technological progress C_{10}
	Environment index A_3	Use of resources B_5	Comprehensive energy consumption per unit of industrial added value C_{11}
			Fresh water consumption per unit of industrial added value C_{12}
			Gross industrial output value per unit of industrial land C_{13}
			Industrial water recycling rate C_{14}
			Comprehensive utilization rate of industrial solid waste C_{15}
			Rate of water reuse C_{16}
		Pollution control B_6	The COD Emissions of per unit of industrial added value C_{17}
			The SO_2 Emissions of per unit of industrial added value C_{18}
			Centralized sewage treatment rate C_{19}
			Harmless treatment rate of garbage C_{20}
			Hazardous waste disposal rate C_{21}
			Waste treatment facilities C_{22}
	Management index A_4	Policy and law B_7	The construction of the parks' environment management system C23
			Rationality of resource development planning C_{24}
		Management & consciousness B_8	The enterprise scale of passing cleaner production audit and acceptance C_{25}
			The parks' changing monitoring capacity C_{26}
		Public recognition B_9	Public satisfaction with the environment C_{27}
			Public awareness rate of the eco-industrial C_{28}

3.2 The multi-level fuzzy comprehensive evaluation mathematical model

Set $U=\{U_1,U_2,U_3,\ldots,U_m\}$

$V=\{V_1,V_2,V_3,V_4,V_5\}=\{$good, secondary, common, relatively poor, poor$\}$

U is the index set, V is the evaluation set, that is the collection evaluation index.

Set R is the total evaluation matrix which composed by m evaluation index, $R=(r_{ij})_{mn}$, that is

$$R=\begin{bmatrix}R_1\\R_2\\\vdots\\R_i\end{bmatrix}=\begin{bmatrix}r_{11}&r_{12}&\cdots&r_{1n}\\r_{21}&r_{22}&\cdots&r_{2n}\\\vdots&\vdots&&\vdots\\r_{m1}&r_{m2}&\cdots&r_{mn}\end{bmatrix}$$

In above formula, $R_i=r_{i1},r_{i2},\cdots,r_{in}$) （i=1,2,⋯,m）is the single factor fuzzy evaluation relating to index U_i. It is fuzzy subset of evaluation set V. r_{ij} is the membership of V_j. V_j is the comment which is given to index U_i.

The weight set $A=\{a_1,a_2,\cdots,a_m\}$ is the fuzzy subset of the index set U. It reflects each index's importance. The ai is the weight of index U_i. And it must meet $\sum_{i=1}^{m}a_i=1, a_i\geq 0$, that each index's weight must meet the normalized requirement. The fuzzy comprehensive evaluation B is the fuzzy subset of evaluation set V, and

$$B=AR=[a_1,\quad a_2,\quad \cdots\quad a_m]\begin{bmatrix}r_{11}&r_{12}&\cdots&r_{1n}\\r_{21}&r_{22}&\cdots&r_{2n}\\\vdots&\vdots&&\vdots\\r_{m1}&r_{m2}&\cdots&r_{mn}\end{bmatrix}=[b_1,b_2,\cdots,b_n]$$

It used the model to evaluate the eco-industrial parks, and took the comparison of starting a project or not. Each program has 28 evaluation index, so n=2, m=28.

3.3 Calculating the total weight value of each factor (evaluation index)

It used the method of Delphi and DHP to calculate the weight value. At first, it used Delphi to determine the relative importance of each index. After passing the consistency test, it used DHP to take statistical calculations to calculate the weight value of each index. When using Delphi to determine the relative importance, the questionnaire for the 28 indexes must be listed, and it must attach related information and explanation. Then it was distributed to the experts to give each index's weight according to personal experience. The sum of the indexes' weight on each level should be 1. When determining the weight at the eco-industrial parks' evaluation, the invited experts should include the experts of government, the planned economy and some related management departments, besides technology leadership and business experts. On the basis of this, the weight vector A in the mathematical model could be calculated.

3.4 Determining the membership degree of each factor (evaluation index)

The prepared evaluation index could divide into two categories of quantitative indexes and qualitative indexes. It used fuzzy mathematics method to calculate the membership degree of quantitative indexes, and the membership degree of qualitative indexes was determined by fuzzy statistical method.

3.4.1 Determining the membership degree of quantitative indexes

According to the information of some related management or statistics department, the membership degree of quantitative indexes could be constructed. When the quantitative indexes were the bigger the better, it used maximum optimal function. That is

$$u(x)=\begin{cases}1 & x\geq a_2\\ \dfrac{x-a_1}{a_2-a_1} & a_1\leq x\leq a_2\\ 0 & 0\leq x\leq a_1\end{cases}$$

When the quantitative indexes were the smaller the better, it used minimal optimal function. That is

$$u(x)=\begin{cases}1 & 0\leq x\leq a_1\\ \dfrac{a_2-x}{a_2-a_1} & a_1\leq x\leq a_2\\ 0 & a_2\leq x\end{cases}$$

3.4.2 Determining the membership degree of qualitative indexes

The qualitative indexes in the project were just determined by the fuzzy statistical method.

At first, the evaluation set V and the standard membership degree set V should be determined.

$V=\{V_1,V_2,V_3,\ldots V_k\}$,$U=\{U_1,U_2,U_3,\ldots U_k\}$

The V and U in the project were determined like this:

$V=\{V_1$(good)，V_2(secondary)，V_3(common)，V_4(relatively poor)，V_5(poor)$\}$

U= {U_1 (1.0), U2 (0.75), U3 (0.25), U5 (0.0)}

According to the result, the evaluation decision vector was $B=[x_1, x_2]$, x_1 was the evaluation result of having Project, x_2 was the result of having not project. If $x_1>x_2$, it reflected that the evaluation result of the eco-industrial parks' evaluation was good, and it was better than no project.

4. The conclusion

The eco-industrial park was a very complex system project, the factors involved were very numerous and there were many methods which could be used. So we should study further. Based on summarizing existing research on eco-industrial parks' evaluation, the article constructed the evaluation index system which included economy, society, environment and management. Then using the multi-level fuzzy comprehensive evaluation model, it evaluated the eco-industrial parks. The method was easy and reasonable, but it exist many problems too. And it should be studied further in the future.

(1) The calculation of each factor's weight had some artificiality, and different experts would give different value.

(2) The realization of some evaluation index was the result of multiple factors, and the eco-industrial park was one of them. So there was the problem of reasonable sharing between all the multiple factors. The study should be strengthened in the future and be solved in the practice.

(3) It was considered that put the other currently used evaluation methods, such as BP neural network model, data envelopment analysis model and dissipative structure model, etc. apply to the eco-industrial parks' evaluation, or put the method used in the article apply to the other similar fields.

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